XIV. *Researches on the Refraction, Dispersion, and Sensitiveness of Liquids.*

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IN a previous paper "On the Influence of Temperature on the Refraction of Light*," we started some inquiries which have been since pursued, and we now lay before the Royal Society some of the later results.

The same apparatus has been employed, with a hollow prism of 61° 0′ angle, and the method of observation has been essentially the same. But experience has led to some modifications, the most important of which is this: instead of attempting to take the angular measurements at certain foredetermined temperatures, as 10° C., 20° C., they were taken first at the temperature of the room, whatever that might be, and then at such other temperatures as seemed to offer the most trustworthy results. This involved more calculation, but it still saved time, and secured greater accuracy. The plan of measuring to 10″ was abandoned as a useless nicety; but, as a rule, two or more observations of each fixed line at each temperature were taken, and if they differed slightly the mean was adopted, but if the discrepancy amounted to 2′ or 3′ the observation was repeated. The average of these observations of the lines A, D, and H at different temperatures gave the refractive indices which are placed together in the Table that constitutes Appendix I., and they afford the data for nearly all the comparisons about to be instituted. Appendix II. contains the mean determinations made of the refractive indices of some of these liquids for a larger number of the lines at the temperature of the room. To it have been added some observations on other liquids, and determinations published in our former papers, so as to render it as complete as possible for any who may desire to investigate the irrationality of the spectrum, or the truth of the formulæ of CAUCHY.

An attempt has been made to determine the amount of probable error, not so much absolutely as with reference to the different purposes for which the observations have been made. The conclusions arrived at are as follows:—

Where the refraction of different fixed lines at the same temperature is compared, the probable error is very small. The measurements may be easily obtained accurate to ±1′, corresponding to about ±0·0002 in the refractive index, and thus the relative refraction of A, D, and H in Appendix I., or of all the lines in Appendix II. for any one substance will rarely differ from the truth by more than that amount.

When the refraction of a substance at one temperature is compared with its refraction

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* Philosophical Transactions, 1858, p. 887.

at another temperature, there exists a source of error in the determination of the precise temperature of that part of the liquid through which the solar beam is passing at the time when the measurement is taken. It is difficult to avoid this error, or to estimate its amount. It is, as may be supposed, generally greatest at the temperatures furthest removed from that of the surrounding objects, and in these cases there is reason to fear that it not unfrequently amounts to 1 or 2 degrees Centigrade. Even at the ordinary temperature an error may arise from the heating power of the sunbeam that passes through the liquid, and which may not affect the thermometer equally with the substance whose refraction is measured. In some of our more exact and our later determinations a strong solution of alum in a flat-sided glass was interposed in the path of the ray to reduce its heating power.

Where the refraction of one substance is compared with that of another, error may also arise from inaccuracy in obtaining the minimum deviation. Though several adjustments have to be made, the error from this source is practically confined within very narrow limits, and rarely if ever passes beyond the fourth place of decimals even with very dispersive substances. This error was not so well guarded against in the observations recorded in our previous paper; and it may also affect the determination of the sensitiveness of a few substances, namely those where a different adjustment of the prism was made at different temperatures; but these are easily known, as that was only done for low temperatures such as 8° C., and they are all marked in Appendix I. with an asterisk. In order to be rigidly correct, the hollow prism ought to have been adjusted afresh for minimum deviation in the case of each line and at each temperature, but the movement of the apparatus necessitated by this would practically have introduced greater errors than resulted from the neglect of it. Yet this has an appreciable effect on the length of the spectrum in highly dispersive substances; and in order to obviate the error as much as possible in the later measurements of such substances, care was taken to fix the minimum deviation not for either of the extremities, but for the middle of the spectrum. It would not have been difficult to make a correction by the usual formula for a small deviation from the minimum angle, but we doubted whether practically anything would be gained, considering the greater complexity of the calculation.

If the indices of refraction were to be considered not relatively, but absolutely, other sources of error would have to be taken into account; for instance, inaccuracy in the determination of the prism-angle, faults of workmanship in the apparatus. For these it is more difficult to assign a limit: they may even affect the third place of decimals, whereas the combined errors from all the other sources are probably confined to the fourth place. But the *absolute* accuracy of an index is of minor importance in the present research.

The purity of the liquids experimented on is of course a matter of the utmost consequence. When commercial specimens were employed they were always purified, or their purity ascertained. Many of the liquids were prepared in Dr. GLADSTONE'S laboratory with special reference to this inquiry, and many others were kindly placed at our disposal by those chemists who had paid special attention to them, and we have generally taken their word for the purity of the specimen. In this way we are under obligations to Professor WILLIAMSON, Professor HOFMANN, Professor FRANKLAND, Dr. WARREN DE LA RUE and Dr. HUGO MÜLLER, Mr. BUCKTON, Dr. ODLING, Mr. A. H. CHURCH, Mr. GREVILLE WILLIAMS, and Mr. PIESSE, to whom we return our best thanks.

The present paper takes up five points.

I. The relation between sensitiveness and the change of volume by heat.

II. The refraction and dispersion of mixed liquids.

III. The refraction, dispersion, and sensitiveness of different members of homologous series.

IV. The refraction, dispersion, and sensitiveness of isomeric liquids.

V. The effect of chemical substitution on these optical properties.

SECTION I.—*The relation between Sensitiveness and the Change of Volume by Heat.*

Having examined now about ninety different liquids, we have uniformly found that the refraction diminishes as the temperature increases. This property we have already named "sensitiveness."

We have uniformly found also that the spectrum diminishes in length as the temperature increases. In a very few instances this diminution is lost within the limits of errors of observation, but we believe it always occurs.

This diminution in length is progressive, the different rays being more sensitive in the order of their refrangibility. The following observations on a most dispersive and sensitive substance exhibit this:—

Substance.	Temp.	Refractive indices.						
		A.	B.	D.	E.		G.	H.
Bisulphide of Carbon.........	°C. 11	1·6142	1·6207	1·6333	1·6465	1·6584	1·6836	1·7090
Bisulphide of Carbon.........	36·5	1·5945	1·6004	1·6120	1·6248	1·6362	1·6600	1·6827
Difference	......	0·0197	0·0203	0·0213	0·0217	0·0222	0·0236	0·0263

That there is some intimate connexion between the sensitiveness of a liquid and its change of volume by heat was pointed out in our former paper; and our subsequent experiments only confirmed this opinion.

It became therefore a matter of interest to determine, if possible, what this relation is. The determinations of the sensitiveness of bisulphide of carbon, water, benzole, alcohol, wood-spirit, fousel-oil, ether, acetone, acetic acid, formic, acetic, and butyric ethers, and the iodides of methyl and ethyl afforded an opportunity of examining the matter, since the alteration of their volume by heat has been very accurately determined by KOPP and others; cumole, xylole, nitrobenzole, hydrate of phenyl, oil of turpentine, rectified oil of Portugal, eugenic acid, bromoform, and salicylate of methyl also answered the same purpose, since we determined the expansibility of the specimens employed for measuring the refractive indices at different temperatures.

In the case of every one of these liquids the refractive index of any ray alters less rapidly than the volume; but it was found that the refractive index minus unity, multiplied by the volume, gives nearly a constant.

It is otherwise with the contraction of the spectrum itself. In some cases, as bisulphide of carbon, it contracts much more rapidly than the volume increases, and in other cases, as ether, much less rapidly.

Here it must be borne in mind that every refractive index contains at least two coefficients. Whatever may be the physical reason, and to whatever extent we may accept such theoretical explanations as those given by CAUCHY, LUBBOCK, Sir WILLIAM HAMILTON, B. POWELL, and others, the formula $\mu=A+\frac{B}{\lambda^2}+\frac{C}{\lambda^4}+\ldots$ does certainly give results very near the truth, μ being the refractive index, λ the length of an undulation, and A, B, C coefficients depending on the nature of the medium. As we must employ A, B, C for the fixed lines of the spectrum so designated by FRAUNHOFER, we shall write the above formula for the future $\mu=\nu+\frac{\varkappa}{\lambda^2}+\frac{\varkappa'}{\lambda^4}+\ldots$ and shall suppose $\varkappa'$ and all subsequent coefficients too small to be sensible within the limits of error. Hence we have ν the coefficient of refraction, and $\varkappa$ the coefficient of dispersion; and ν may evidently be considered the refractive index of any substance freed from the influence of dispersion. As it appears that the function $\mu-1$ is of peculiar interest in these investigations, we propose giving it a distinct name, that of "*refractive energy*," this number really representing the influence of the substance itself on the rays of light. $(\mu-1)\times$ vol., or, which is the same thing, $\frac{(\mu-1)}{\text{density}}$, we propose calling the "*specific refractive energy*."

As the value of μ for any particular luminous ray is affected by the dispersion, it was clearly desirable to calculate ν in certain cases, and see whether $(\nu-1)\times$ vol. would give a constant. Some doubt rests on the position of this theoretical limit; but its value was calculated by the formula given on pages 82 and 132 of BADEN POWELL's treatise 'On the Undulatory Theory as applied to Dispersion.' It will easily be seen by referring to the example on p. 132, that, in consequence of an accidental relation between the coefficients, $\nu=\mu_H-3(\mu_F-\mu_B)$ to very considerable exactness. This formula has been used by us, but in all cases given below the results have been verified by the accurate one.

Bisulphide of carbon and water were the liquids chosen, being very definite substances and extremely different in their degree of expansibility, water also having the advantage of a very irregular rate of change of volume. The refractive indices of the fixed lines B, F, and H (on which the calculation of ν depends) were determined at different temperatures with every precaution*.

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* The determinations for water in the accompanying Table were substituted during the printing for less accurate numbers.

Substance.	Temp.	Refractive indices.		
		B.	F.	H.
Bisulphide of Carbon...	11°	1·6207	1·6584	1·7090
Bisulphide of Carbon...	22·5	1·6116	1·6484	1·6972
Bisulphide of Carbon...	36·5	1·6004	1·6362	1·6827
Water	1	1·33005	1·33685	1·3431
Water	15·5	1·3298	1·3364	1·3426
Water	27·5	1·3289	1·3355	1·3416
Water	48	1·32595	1·33245	1·3387

The subjoined Table contains the calculations founded on these numbers. Column I. gives the refractive index of the theoretical limit, or ν. Column II. the specific refractive energy for this limit, or $(\nu-1)$ vol. Column III. the specific refractive energy for the line B, or (μ_B-1) vol. Column IV. the same for H, or (μ_H-1) vol. Column V. gives what Newton called the "absolute refractive power" reckoned for the limit, or (ν^2-1) vol.

Substance.	Temp.	Volume.	I.	II.	III.	IV.	V.
Bisulphide of Carbon...	11°	0·9554	1·5960	0·5694	0·5930	0·6773	1·4782
Bisulphide of Carbon...	22·5	0·9685	1·5865	0·5680	0·5923	0·6752	1·4714
Bisulphide of Carbon...	36·5	0·9854	1·5753	0·5669	0·5916	0·6727	1·4599
Extreme difference......	25·5	0·0300	0·0207	0·0025	0·0014	0·0046	0·0183
Water	1	0·9999	1·3227	0·3227	0·3300	0·3431	0·7495
Water	15·5	1·0007	1·3228	0·3230	0·3300	0·3429	0·7497
Water	27·5	1·0034	1·3216	0·3227	0·3300	0·3428	0·7492
Water	48	1·0109	1·3193	0·3227	0·3295	0·3429	0·7486
Extreme difference......	47	·0110	0·0035	0·0003	0·0005	0·0003	0·0011

It thus appears that the specific refractive energy is nearly a constant, whether we take the limit ν or the line B as the basis of calculation. The "absolute refractive power" is evidently not a constant.

The following Table exhibits the specific refractive energy at various temperatures for some of the other liquids mentioned above, the selection being made not of those which give the most accordant results, but of those which may be considered representative bodies, or of which we happen to possess observations at the longest range of temperature. The columns are numbered as before, the only difference being that in Column III. the line A is taken instead of B. The refractive indices observed will be found in Appendix I., or in our previous paper.

Substance.	Temp.	Volume.	I.	II.	III.	IV.
Alcohol	0°	0·9132	1·3598	0·3286	0·3340	0·3480
Alcohol	20	0·9326	1·3518	0·3280	0·3337	0·3478
Alcohol	40	0·9534	1·3435	0·3275	0·3332	0·3473
Alcohol	60	0·9762	1·3347	0·3268	0·3326	0·3473
Difference	......	+0·0630	—0·0251	—0·0018	—0·0014	—0·0007
Formic Ether............	22	1·0305	1·3476	0·3582	0·3650	0·3807
Formic Ether............	31	1·0436	1·3434	0·3584	0·3653	0·3811
Formic Ether............	40	1·0573	1·3390	0·3584	0·3654	0·3815
Difference	......	+0·0268	—0·0086	+0·0002	+0·0004	+0·0008
Iodide of Ethyl	23·5	0·9440	1·4878	0·4604	0·4720	0·5116
Iodide of Ethyl	36	0·9583	1·4795	0·4595	0·4712	0·5103
Iodide of Ethyl	48	0·9730	1·4718	0·4590	0·4710	0·5108
Difference	......	+0·0290	—0·0160	—0·0014	—0·0010	—0·0008
Acetic Acid	20·5	1·0228	1·3656	0·3739	0·3794	0·3969
Acetic Acid	28·5	1·0305	1·3624	0·3734	0·3792	0·3967
Acetic Acid	40	1·0432	1·3579	0·3733	0·3791	0·3964
Acetic Acid	47·5	1·0517	1·3543	0·3726	0·3786	0·3963
Difference	......	+0·0289	—0·0113	—0·0013	—0·0008	—0·0006
Benzole	10·5	1·0125	1·4777	0·4836	0·4940	0·5371
Benzole	23	1·0278	1·4704	0·4834	0·4939	0·5370
Benzole	39	1·0481	1·4601	0·4822	0·4929	0·5353
Difference	......	+0·0356	—0·0176	—0·0014	—0·0011	—0·0018
Oil of Turpentine	24	1·1621	1·4521	0·5253	0·5341	0·5630
Oil of Turpentine	41	1·1778	1·4449	0·5240	0·5323	0·5611
Oil of Turpentine	47	1·1831	1·4414	0·5222	0·5308	0·5594
Difference	......	+0·0210	—0·0107	—0·0031	—0·0033	—0·0036
Eugenic Acid............	18	0·9349	1·5159	0·4818	0·4942	0·5403
Eugenic Acid............	27·5	0·9412	1·5119	0·4817	0·4934	0·5383
Difference	......	+0·0063	—0·0040	—0·0001	—0·0008	—0·0020

These results suffice to show that any refractive index minus unity, multiplied into the volume or divided by the density, gives nearly a constant. Indeed the numbers generally fall within the limits of experimental error. It is worthy of notice, too, that in the majority of cases, as bisulphide of carbon or alcohol, the products show a tendency to diminish as the temperature rises; but there are other cases, as formic ether, where the tendency seems to be to increase. Again, in some cases $(\nu-1)$ vol. gives the most accordant results; in other cases (μ_H-1) vol.

Supposing this true of the coefficient of refraction, does the law equally hold good of the coefficient of dispersion? It is evident from the formula $\mu=\nu+\frac{\kappa}{\lambda^2}$ that in the difference of any μ and ν, or of the refractive indices of any two rays, we have a measure of the coefficient of dispersion $\varkappa$. For convenience sake we adopt $\mu_H - \mu_A$ as this measure; and this is what is headed "Dispersion" in many subsequent tables. It is the same as "Length of Spectrum" in our former paper. This, multiplied by the volume, or $(\mu_H - \mu_A)$ vol., we call "Specific Dispersion." But, as already stated, there is no simple relation holding good for different liquids between the increase of volume and the decrease of dispersion by heat. The phenomena seem independent.

We therefore arrive at the empirical law, that *the refractive energy of a liquid varies directly with its density under the influence of change of temperature*, or, *in other words, that the specific refractive energy of a liquid is a constant not affected by temperature.* But in concluding thus, we wish it to be borne in mind that there is some influence, arising wholly or partially from dispersion, which we have not been able to take into account, but which gives rise to the slight progression of most of the calculated products, and perhaps to the non-inversion of the sensitiveness of water at 4° C., remarked on already by JAMIN and ourselves.

SECTION II.—*The Refraction and Dispersion of Mixtures of Liquids.*

This subject engaged the attention of M. DEVILLE as far back as 1842 [*]; and of late years Messrs. HANDL and A. and E. WEISS [†] have published elaborate papers on it, but without arriving at a solution of the question. M. HOEK [‡], however, proceeding on the assumption of FRESNEL, that the density of the ether enclosed in a medium is $\mu^2 - 1$ if the density of the ether in space is 1, found that the formula deduced from it gave numbers closely agreeing with those found experimentally by DEVILLE for mixtures of alcohol and water, or wood-spirit and water. Yet it happens that these results can equally well be explained on the supposition that the specific refractive power of a mixture is the mean of the specific refractive power of its components. And this supposition seemed also warranted by most of the results of Messrs. WEISS, and by several that we ourselves obtained.

It was clearly desirable to test these two, or any other suppositions, in a case where the refractive indices of the liquids mixed were very wide apart. Fortunately bisulphide of carbon and ether, substances almost at the opposite limits of the scale, were found to mix, and that without perceptible condensation, not indeed in equal volumes, but in the proportion of three volumes of ether to one of the bisulphide at low temperatures, and in the proportion of two to one at 20° C.

Two experiments were made at different seasons on mixtures of commercially pure specimens of these substances. The greatest care was taken to prevent evaporation as far as possible during the progress of the experiments.

It will be seen that in a case such as this, where there is no condensation on mixture, the calculation is much simplified, since for the specific refractive powers we may sub-

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[*] Ann. de Chim. et de Phys. (sér. 3) tome v. p. 129.

[†] Wien. Ber. xxv. xxx. xxxi. and xxxiii. 589–656.

[‡] Poggendorff's Annalen, cxii.

stitute the refractive indices themselves, and the supposition will stand thus: the refractive index of a mixture is the mean of the refractive indices of its components. And in such a case HOEK's formula resolves itself into the mean of μ^2-1.

Liquid.	Temperature.	Specific gravity.	Refractive index.		
			A.	D.	H.
Bisulphide of Carbon.........	8° C.	1·2790	1·6184	1·6366	1·7093
Ether	8	0·7374	1·3542	1·3575	1·3692
Mixture of 1 vol. Bisulph. and 3 vols. Ether	8	0·8710	1·4165	1·4235	1·4480
Mean	8	....	1·4202	1·4272	1·4542
Hoek's theory	8	....	1·4247	1·4323	1·4619
Bisulphide of Carbon.........	20	1·2685	1·6121	1·6299	1·7008
Ether	20	0·7246	1·3487	1·3525	1·3636
Mixture of 1 vol. Bisulph. and 2 vols. Ether	20	0·9059	1·4305	1·4390	1·4686
Mean	....	....	1·4365	1·4450	1·4760
Hoek's theory	....	....	1·4417	1·4509	1·4845

These two experiments confirm one another, but they fail to support either hypothesis. The calculation founded on μ^2-1 gives numbers which are far too high; and though the mean of the indices is certainly much nearer to the calculated numbers, the discrepancy in each case is beyond the limits of probable error. The calculation for A is certainly nearer than that for H, but evidently not much would be gained by assuming the theoretical limit as the basis of calculation.

Similar experiments were made by mixing aniline and alcohol of 90 per cent. together in equal volumes, but in this case a slight condensation ensues.

Liquid.	Temperature.	Specific gravity.	Refractive indices.		
			A.	D.	H.
Aniline	23·5° C.	1·0073	1·5642	1·5772	1·6263
Alcohol, 90 per cent..........	23·5	0·8154	1·3576	1·3614	1·3729
Mixture of equal vols., mean of two experiments	23·5	0·9167	1·4621	1·4707	1·5018
Mean deduced from specific refractive powers...	23·5	....	1·4636	1·4721	1·5025
Hoek's theory	....	....	1·4668	1·4754	1·5070

This shows precisely the same thing as the previous mixture; and, as in that case, the experimental numbers are slightly below those deduced from the mean of the specific refractive powers. This is also the case in other mixtures examined; yet no other simple formula gives numbers so closely approaching those obtained by experiment. The hypothesis that *the specific refractive power of a mixture of liquids is the mean of the specific refractive powers of its constituents* must therefore stand as the nearest approximation to the truth.

In one or two cases, as in the mixtures of sulphuric acid and water examined by Messrs. WEISS, the refraction is not at all in accordance with the above theory. This probably arises from some chemical combination between the two substances, different hydrates being formed.

We hope to revert to this subject more fully on some future occasion, when we propose extending our inquiry to solutions of solids.

SECTION III.—*The Refraction, Dispersion, and Sensitiveness of different members of Homologous Series.*

In our paper on the influence of temperature we remarked an advance in refraction and dispersion with each increment of $C_2 H_2$ in the alcohol series. This has been examined more carefully, and the investigation has been carried much further in the same direction. The new data for the comparisons are given in Appendix I., from which the subsequent Tables are calculated, a reduction of the indices to 20° C. of temperature being always made, and the sensitiveness being calculated for 10 degrees rising from that temperature. The length of the spectrum, or the dispersion, is also reckoned at 20° C. The refractive index for only one line is given, in order to save space; and A is the line chosen, as it is least affected by dispersion. Where two specimens of the same substance have been examined, the mean of the observations has usually been adopted.

The Alcohol Series.

Liquid.	Formula.	Refractive index of A at 20° C.	Length of spectrum or dispersion.	Sensitiveness for 10° C.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Methylic Alcohol	$C_2 H_4 O_2$	1·3268	0·0128	0·0036	0·4105	0·0163	0·0045
Ethylic Alcohol.........	$C_4 H_6 O_2$	1·3578	0·0151	0·0041	0·4482	0·0190	0·0052
Amylic Alcohol.........	$C_{10} H_{12} O_2$	1·4005	0·0174	0·0039	0·4895	0·0212	0·0047
Caprylic Alcohol	$C_{16} H_{18} O_2$	1·4186	0·0195	0·0042	0·5096	0·0237	0·0051

From this it is evident that on ascending the series the refraction increases, the dispersion more rapidly still, while the sensitiveness remains nearly the same.

It should be borne in mind that on account of the small numbers by which the sensitiveness is expressed, and the serious source of error arising from the difficulty of determining the temperature with accuracy, comparisons of the sensitiveness of different liquids cannot be so satisfactory as comparisons of their refractive indices, or the length of the spectrum. As all the degrees of sensitiveness at 20° C. known to us lie between 0·0007 and 0·0074, we propose in future omitting the zeros, and simply stating that the sensitiveness of methylic alcohol for instance is 36. We shall omit the zeros also in the last three columns.

As we have already learnt the importance of comparisons of specific refractive energy, we have added in the three last columns the refractive energy ($\mu_A - 1$), the dispersion ($\mu_H - \mu_A$), and the sensitiveness (μ_A at 20° C.$-\mu_A$ at 30° C.), all divided by the density. It will be seen that the progression is maintained.

But some might prefer that the different alcohols should be compared, not at the same absolute temperature, but at the same distance from their boiling-points. This is attempted in the following Table for 82° below the boiling-points, but as the observations do not extend nearly to that in the case of methylic or caprylic alcohols, there is more left for calculation than is desirable.

Liquid.	Temperature.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refraction.	Specific dispersion.	Specific sensitiveness.
Methylic Alcohol	° − 22	1·3410	0·0135	33	4079	161	40
Ethylic Alcohol.........	− 4	1·3674	0·0154	40	4515	189	49
Amylic Alcohol.........	+ 50	1·3888	0·0167	40	4914	211	50
Caprylic Alcohol	100	1·3807	0·0180	51	5123	242	68

Here the advance of the refraction and dispersion with each addition of $C_2 H_2$ appears again (with one exception), and the sensitiveness advances likewise; and this is still more evident when the numbers are divided by the density.

It was a matter of interest to compare with these results the refractive indices of other homologous series belonging to the same group.

Iodide of Methyl Series.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Iodide of Methyl	$C_2 H_3 I$	1·5171	0·0460	73	2359	209	33
Iodide of Ethyl	$C_4 H_5 I$	1·5026	0·0420	66	2614	218	34
Iodide of Propyl	$C_6 H_7 I$	1·4934	0·0408	63	2882	235	36
Iodide of Amyl	$C_{10} H_{11} I$	1·4804	0·0335	50	3213	224	33

In this case the refraction, dispersion, and sensitiveness are also progressive, but in the opposite direction, for they all decrease as we ascend the series, instead of increasing, as was the case with the alcohols. This may be attributed to the larger proportion of iodine which the earlier members of the series contain, for iodine has a very great influence on the rays of light. If the numbers be divided by the specific gravity, the progression becomes in the direction of increase as with the alcohols, both in regard to refraction and dispersion, while in regard to sensitiveness the four members give nearly the same number, as was also the case in the series of alcohols.

Formic Ether Series.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Formic Ether	$C_4 H_5 O, C_2 H O_3$	1·3549	0·0154	44	3905	168	48
Acetic Ether	$C_4 H_5 O, C_4 H_3 O_3$	1·3659	0·0157	48	4152	178	55
Propionic Ether.........	$C_4 H_5 O, C_6 H_5 O_3$	1·3707	0·0164	44	4333	191	51
Butyric Ether	$C_4 H_5 O, C_8 H_7 O_3$	1·3864	0·0168	48	4402	191	54
Valerianic Ether	$C_4 H_5 O, C_{10} H_9 O_3$	1·3908	0·0172	42	4502	198	48

Here, as in the case of the alcohols, there is a progressive increase of refraction, dispersion, and specific energy. The numbers representing the sensitiveness appear rather irregular, but it is difficult to say how far this may be due either to impurity of specimens or to errors of observation.

During the progress of these experiments we found Professor DELFFS has preceded us in examining the refraction of members of the formic ether series[*]. He gives as the indices of the red ray—

Formic Ether	1·3570
Acetic Ether	1·3672
Butyric Ether	1·3778
Valerianic Ether . . .	1·3904
Œnanthylic Ether . .	1·4144
Laurostearic Ether . .	1·4240

He does not note the temperature. His conclusion is, that "the indices of refraction of the compound ethers increase with their equivalents." His experiments afforded him no means of drawing a conclusion in regard to the dispersion; and the sensitiveness was a property not fully recognized at that time.

Acetate of Ethyl Series.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Acetate of Ethyl	$C_4 H_5 O, C_4 H_3 O_3$	1·3659	0·0157	48	4152	178	55
Acetate of Amyl	$C_{10} H_{11} O, C_4 H_3 O_3$	1·3911	0·0172	43	4506	198	49
Acetate of Capryl	$C_{16} H_{17} O, C_4 H_3 O_3$	1·4088	0·0211	58	......	......	...

This resembles the preceding series, or that of the alcohols, as might be anticipated. Professor DELFFS in his second paper gives

Acetate of Methyl	1·3576
Acetate of Ethyl	1·3672
Acetate of Amyl	1·3904

He also gives the following indices, which bear similar witness:—

Butyrate of Methyl . . .	1·3752	Oxalate of Amyl	1·4168
Butyrate of Ethyl . . .	1·3778	Formiate of Ethyl . . .	1·3570
Butyrate of Amyl . . .	1·4024	Formiate of Amyl . . .	1·3928
Oxalate of Ethyl	1·3803		

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[*] Poggendorff's Annalen, lxxxi. 470.

Hydride Series.

Liquid.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Hydride of Œnanthyl	$C_{14}H_{15}H$	1·3898	0·0172	55	5499	242	77
Hydride of Capryl	$C_{16}H_{17}H$	1·3971	0·0170	47	5522	236	65

This also bears similar evidence.

Mercuric and Stannic Series.

Through the kindness of Mr. Buckton and Dr. Frankland, we have been able to examine some of the combinations of the metals with the compound radicals. Unfortunately the specimens had all suffered a partial decomposition on standing, and thus the results are not so trustworthy as might be desired.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Mercuric Methyl	C_2H_3Hg	1·5241	0·0431	43	1707	140	14
Mercuric Ethyl...............	C_4H_5Hg	1·5162	0·0416	?	2112	170	?
Stannic Ethyl-methyl ...	$\left.\begin{matrix}C_2H_3\\C_4H_5\end{matrix}\right\} Sn$	1·4550	0·0313	50	3727	256	41
Stannic Ethyl	$(C_4H_5)_2Sn$	1·4621	0·0301	50	3876	268	42

The specific index here, as in every preceding case, increases with the addition of C_2H_2; the great absolute influence of mercury on the rays of light makes itself manifest, as iodine did, in the inversion of the order of progress in regard to actual refraction and dispersion; it should be remembered that mercuric methyl contains close upon 87 per cent. of mercury.

It is worthy of notice that in the two series last given there occur the heaviest and about the lightest known liquid in the whole range of organic chemistry; and the light hydride of œnanthyl has a very high, and the heavy mercuric methyl a very low specific refractive energy.

All these series containing the compound radicals methyl and its congeners, agree in exhibiting a progressive change in refraction and dispersion with the advancing members of the series; but in which direction and to what extent depend on the other substances with which the radical is combined. Yet, if we regard not the actual indices, but these minus unity, divided by the specific gravity, we find an invariable increase as the series advances. The following Tables exhibit this:—

Specific Refractive Energy.

Radical.	Formula.	Alcohol.	Iodide.	Ether of acid.	Formiate.	Acetate.	Butyrate.	Oxalate.	Mercuric compound.	Stannic compound.	Hydride.
Methyl	$C_2 H_3$	4105	2359	3905	...	...	...	...	1707	3727*	...
Ethyl	$C_4 H_5$	4482	2614	4152	3905	4152	4402	3502	2112	3876	...
Propyl	$C_6 H_7$	...	2882	4333	...	...	...	...	...	...	...
Butyl	$C_8 H_9$	...	...	4402	...	...	...	...	...	...	...
Amyl	$C_{10} H_{11}$	4895	3213	4502	4432	4506	4724	4306	...	...	...
Œnanthyl	$C_{14} H_{15}$	...	...	4750	...	...	...	...	...	...	5499
Capryl	$C_{16} H_{17}$	5096	...	...	...	...	...	...	...	...	5522
Laurostearyl	$C_{24} H_{25}$	...	...	4890	...	...	...	...	...	...	...

Specific Dispersion.

Radical.	Alcohol.	Iodide.	Ether of acid.	Acetate.	Mercuric compound.	Stannic compound.	Hydride.
Methyl	163	209	168	...	140	256*	...
Ethyl	190	218	178	178	170	268	...
Propyl	...	235	191	...	...	...	...
Butyl	...	...	191	...	...	...	...
Amyl	212	224	198	198	...	...	...
Œnanthyl	...	...	...	...	...	...	242
Capryl	237	...	...	...	...	...	236

Other Homologous Series.

It seemed desirable to examine other groups of homologous bodies in order to see whether there existed in them the same progressive change in the optical properties answering to the progressive additions of the increment $C_2 H_2$. Through the kindness of Mr. Church and others we were able so to test the benzole, the pyridine, and the chinoline series.

Benzole Group.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Benzole	$C_{12} H_6$	1·4823	0·0419	60	5564	483	69
Toluole	$C_{14} H_8$	1·4835	0·0402	55	5584	464	63
Xylole	$C_{16} H_{10}$	1·4835	0·0408	58	5583	472	67
Cumole	$C_{18} H_{12}$	1·4819	0·0377	52	5547	425	60
Cymole	$C_{20} H_{14}$	1·4696	0·0312	53	5454	362	61

The first four members of this series, all of which were derived from coal-tar, bear a close resemblance to one another, instead of showing that progression in refractive and dispersive properties which marks all the series of the preceding group. Cymole gives lower numbers; but the difficulties arising from isomerism, which we shall shortly advert to, render any deduction from this group very doubtful.

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* This compound contains both methyl and ethyl.

Hydrate of Phenyl Series.

Allied to benzole and toluole are the two main constituents of creasote.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Hydrate of Phenyl......	$C_{12} H_5 O, HO$	1·5344	0·0503	46	5034	475	43
Hydrate of Cresyl......	$C_{14} H_7 O, HO$	1·5319	0·0467	33	5122	450	32

Pyridine Group.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Pyridine..................	$C_{10} H_5 N$	1·4948	0·0447	55	5081	458	56
Picoline	$C_{12} H_7 N$	1·4902	0·0427	56	5132	446	57
Lutidine..................	$C_{14} H_9 N$	1·4909	0·0416	?	5244	448	?
Collidine..................	$C_{16} H_{11} N$	1·4946	0·0404	51	5370	444	53

In this series the actual refractive indices are nearly the same, but somewhat irregular; yet the density is progressive, and in such a manner that when the refractive power is divided by it, a series of increasing numbers is obtained. The dispersion decreases regularly and more rapidly than the density does, so that an addition of $C_2 H_2$ yields a lower number in regard to specific dispersion, though a higher one in regard to specific refractive energy.

Chinoline Group.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Chinoline	$C_{18} H_7 N$	1·5590	0·0631	55	5170	583	50
Lepidine	$C_{20} H_9 N$	1·6045	0·0783	58	5639	730	54

In this case, unlike the pyridine group, which it so closely resembles (chemically speaking), the refraction and dispersion increase rapidly, whether we consider the absolute numbers or these divided by the specific gravity.

Lepidine, kindly given by its discoverer Mr. C. GREVILLE WILLIAMS, proves to be the most refractive organic liquid known, very nearly equalling bisulphide of carbon.

This examination of other homologous groups shows that *the influence of each addition of* $C_2 H_2$, *which was observable throughout the series of the methyl group, does not necessarily hold good when we pass to substances of quite another type.*

POSTSCRIPT TO SECTION III., *February* 26, 1863.—A few days after the above was presented to the Royal Society, we observed, on taking up the last number of Poggendorff's

Annalen (cxvii. 353), a paper by M. LANDOLT "On the Refractive Indices of Fluid Homologous Compounds." He has examined, evidently with great care, the acids of the $C_n H_n O_4$ type, and finds that on ascending the series the refraction and dispersion increase, and the sensitiveness very slightly diminishes, with the exception of formic acid, which appears unconformable. This, however, is clearly due to the high density of that acid; and if we divide the numbers of LANDOLT by the densities, the anomaly disappears, and we obtain a series of valuations confirmatory in every way of those drawn out in the preceding Tables. LANDOLT measured, not A and H, but α and γ of the hydrogen light, which are nearly coincident with C and G of the solar spectrum.

Liquid.	Formula.	Specific refractive energy $(\mu_\alpha - 1) \div$ density.	Specific dispersion $(\mu_\gamma - \mu_\alpha) \div$ density.
Formic Acid	$C_2 H_2 O_4$	3024	91
Acetic Acid	$C_4 H_4 O_4$	3517	98
Propionic Acid	$C_6 H_6 O_4$	3860	105
Butyric Acid............	$C_8 H_8 O_4$	4115	114
Valeric Acid	$C_{10} H_{10} O_4$	4318	121
Caproic Acid............	$C_{12} H_{12} O_4$	4449	125
Œnanthic Acid	$C_{14} H_{14} O_4$	4569	129

This also shows, what is apparent both in our Tables given above and in some in Section V., that the amount of optical change is less between the higher than between the lower members of the series.

SECTION IV.—*The Refraction, Dispersion, and Sensitiveness of Isomeric Liquids.*

There are some isomeric bodies which we know differ from one another in their chemical constitution, while there are others to which we cannot yet assign any different arrangement of their elements. We have examined instances of both these classes.

Benzole Group.—This group offers a remarkable number of isomeric bodies differing slightly in their physical and chemical characters:—

Substance.	Boiling-point.	Density.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Benzole	80°·8	·8667	1·4823	0·0419	60	5564	483	69
Parabenzole	97·5	·8469	1·4814	0·0402	...	5684	474	...
Toluole	103·7	·8650	1·4739	0·0377	58	5478	435	67
Paratoluole	119·5	·8333	1·4715	0·0363	59	5658	435	70
Toluole (2nd specimen)	113	·8658	1·4835	0·0402 ?	55	5584	464 ?	63
Cumole (from Cuminic Acid)...	148·4	·8710	1·4825	0·0372	56	5547	427	65
Cumole (from Wood-spirit) ...	149·5	·8580	1·4631	0·0311	51	5400	363	59
Pseudo-cumole (from Coal-tar)	140·5	·8692	1·4819	0·0370	52	5544	425	60
Cymole (from Oil of Cumin)...	171	·8600	1·4696	0·316	53	5460	367	61
Cymole (from Camphor)	170	·8565	1·4693	0·317	48	5478	370	56

Here we have a variety of results:—isomeric bodies probably identical in refractive index, specific energy, and dispersion (cumole from cuminic acid, and Dr. H. MÜLLER's pseudocumole, and the two cymoles); isomeric bodies nearly identical in their actual optical properties, but, on account of a difference in their densities, differing in their specific refractive energy (benzole and parabenzole, toluole and paratoluole); isomeric bodies identical in density, but differing in optical properties (two toluoles); isomeric bodies differing in density, and in each of the optical properties (two cumoles).

Essential Oil Group.—There are a large number of essential oils which consist of carbon and hydrogen in the proportion of 5 equivs. of the first to 4 equivs. of the second, and which differ from one another slightly in physical characters. Through Mr. PIESSE we obtained pure specimens of the crude oils, from which many of these hydrocarbons were prepared, carefully purified, and examined. They are arranged in the following Table according to their boiling-points. When two or more from different plants appeared to be identical, or nearly so, in all their known physical properties except odour, only one is given:—

Substance.	Boiling-point.	Specific gravity.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Hydrocarbon from Turpentine	160°	·8644	1·4612	0·0250	47	·5319	289	55
,, ,, Anise......	160	·8580	1·4608	0·0269	48	·5370	313	56
,, ,, Thyme ...	160	·8635	1·4617	0·0262	48	·5346	326	56
,, ,, Carraway..	160	·8530	1·4610	0·0261	48	·5391	305	56
,, ,, Bergamot..	173	·8467	1·4619	0·0297	49	·5456	350	57
,, ,, Bay	173	·8510	1·4542	0·0257	47	·5337	302	55
,, ,, Cloves ...	252	·9041	1·4898	0·0284	45	·5417	314	50
,, ,, Cubebs ...	259	·9260	1·4950	0·0302	41	·5345	326	44

Here, as in the case of parabenzole and paratoluole, we have five isomeric bodies with sensibly the same refraction 1·461, although there are slight differences in the density and other properties, differences that seem to be real. The dispersion varies considerably; and the difference between turpentine, the least, and bergamot, the most dispersive, is only increased when the difference of density enters into the calculation. The sensitiveness seems the same in each of the five. The hydrocarbon from bay seems slightly lower in refraction; while those from cloves and cubebs, with much higher boiling-points and densities, are much higher in refraction and dispersion, and lower in sensitiveness. The specific refractive energies of the whole group do not differ widely.

Sugars.—We do not propose entering now on the subject of solutions, but we may state that solutions of cane-, grape- and honey-sugar, and gum, of the same strength, gave the same, or very nearly the same, amount of refraction and dispersion.

Compound Ethers.—It is well known that among the compound ethers pairs exist which have the same ultimate composition and similar density, but which are broken up by alkalies into different acids and alcohols. If it does not matter, as to its action on light, whether the increment C_2H_2 be in the electro-positive or electro-negative element, these pairs will present an identity in refraction, dispersion, and sensitiveness. Such indeed seems to be the case.

Liquid.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Valerianic Ether ...	$C_4 H_5 O, C_{10} H_9 O_3$	1·3908	0·0173	42	4502	199	48
Acetate of Amyl ...	$C_{10} H_{11} O, C_4 H_3 O_3$	1·3911	0·0172	43	4506	198	49

In this also we find that Professor DELFFS has preceded us, as far as refraction is concerned. He gives

Formic Ether	1·3570
Acetate of Methyl . .	1·3576

and

Valerianic Ether . . .	1·3904
Acetate of Amyl . . .	1·3904

Aniline and Picoline.—These two bodies have each the ultimate composition $C_{12} H_7 N$, but the action of chemical reagents proves that they are constructed very differently. The following comparison will show that they differ widely in refraction, dispersion, and sensitiveness, even when the difference in specific gravity is taken into account.

Liquid.	Rational formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Aniline	$\left.\begin{matrix} C_{12} H_5 \\ H_2 \end{matrix}\right\} N$	1·5650	0·0653	47	550	635	47
Picoline	$C_{12} H_7''' N$	1·4902	0·0428	56	513	448	59

It thus appears that *isomeric bodies are sometimes widely different in these optical properties; but in many cases, especially when there is close chemical relationship, there is identity also in this respect.*

SECTION V.—*The Effect of Chemical Substitution.*

The doctrine of types and substitution is fully recognized, at least by all the students of organic chemistry. It becomes a matter of interest to determine the amount of change in the optical properties which results from a replacement of one element by another, the type remaining the same. By this means we may attain to a knowledge of the influence of the individual elements on the rays of light transmitted by them. The data for such an inquiry ought to be very numerous, but those which we have already collected point to some conclusions.

The Substitution of Hydrogen by an Organic Radical.

In the following instance the substitution of amyl has not produced much change when the refractive power is divided by the density.

Liquid.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Aniline	$\left.\begin{matrix}C\ \ H^{5}\\ H\end{matrix}\right\}N$	1·5650	0·0653	47	550	635	45
Amyl-aniline ...	$\left.\begin{matrix}C_{12}H_5\\ C_{10}H_{11}\\ H\end{matrix}\right\}N$	1·5130	0·0508	46	559	554	49

But a more interesting case is that of ether, alcohol, and water, which, according to WILLIAMSON, are of the same type,—a theory which the subjoined numbers favour, as the optical properties of the three are analogous, and those of alcohol are intermediate between those of water and ether when the proper allowance is made for the difference of specific gravity. The comparison is made, not at the same temperature, but at 30° below their respective boiling-points.

Liquid.	Williamson's formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Water............	$\left.\begin{matrix}H\\ H\end{matrix}\right\}\Theta$	1·3203	143	24	·3272	145	25
Alcohol	$\left.\begin{matrix}\bar{C}_2H_5\\ H\end{matrix}\right\}\Theta$	1·3460	148	44	·4499	192	57
Ether	$\left.\begin{matrix}\bar{C}_2H_5\\ \bar{C}_2H_5\end{matrix}\right\}\Theta$	1·3575	154	52	·4888	210	70

The Substitution of Hydrogen by Oxygen.

Of the effect of this replacement we have the following instances:—

Liquid.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Alcohol	$\left.\begin{matrix}C_4H_5\\ H\end{matrix}\right\}O_2$	1·3578	0·0151	41	·4482	190	52
Acetic Acid	$\left.\begin{matrix}C_4H_3O_2\\ H\end{matrix}\right\}O_2$	1·3690	0·0172	37	·3483	162	35
Ether	$\left.\begin{matrix}C_4H_5\\ C_4H_5\end{matrix}\right\}O_2$	1·3487	0·0149	51	·4868	208	71
Acetic Ether......	$\left.\begin{matrix}C_4H_5\\ C_4H_3O_2\end{matrix}\right\}O_2$	1·3659	0·0157	48	·4152	178	55
Carvene	$C_{20}H_{16}$	1·4610	0·0261	48	·5391	305	56
Carvole	$C_{20}H_{14}O_2$	1·4886	0·0345	46	·5126	362	48
Eugenic Acid ...	$C_{20}H_{12}O_4$	1·5277	0·0495	42	·4945	463	39

In all these cases the replacement of hydrogen by oxygen has increased the actual refraction and dispersion, but decreased the specific refractive energy.

The two pairs, alcohol and acetic acid, ether and acetic ether, are interesting for comparison, since the chemical change is the same in the two, and it will be observed that the optical change is nearly the same also.

The three last bodies occur together, or under similar circumstances in nature, and form a series of which the second (carvole) is precisely intermediate in composition. It is also intermediate in optical properties.

The Substitution of Hydrogen by Peroxide of Nitrogen.

Of this the following instances have been examined:—

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Benzole	$C_{12} H_6$	1·4823	0·0323*	60	5671	380*	70
Nitrobenzole	$\left.\begin{matrix}C_{12} H_5 \\ (NO_4)\end{matrix}\right\}$	1·5356	0·0501*	50	4610	423*	43
Dinitrobenzole † ..	$\left.\begin{matrix}C_{12} H_4 \\ (NO_4)_2\end{matrix}\right\}$	1·5486	0·0570*	48	3880	404*	34
Glycerine	$C_6 H_8 O_6$	1·4659	0·0191	25	3690	151	19
Nitroglycerine ...	$C_6 H_5(NO_4)_3 O_6$	1·4654	0·0264	45	2909	165	28
Amylic Alcohol...	$C_{10} H_{12} O_2$	1·4005	0·0174	39	4895	212	47
Nitrate of Amyl...	$C_{10} H_{11}(NO_4) O_2$	1·4065	0·0210	45	4061	202	44

Here we observe in the case of the benzole compounds a considerable increase of actual refraction, but in those of glycerine and amylic alcohol little change, while in each case there is a very marked increase of dispersion; yet when the numbers are divided by the density the refraction at least shows a decrease. The sensitiveness is greatly diminished by the substitution in the benzole compounds.

The Substitution of Hydrogen by Chlorine.

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Benzole	$C_{12} H_6$	1·4823	0·0419	60	5564	483	69
Chlorobenzole	$C_{12} H_5 Cl$	1·5135	0·0437	53	4634	394	48
Trichlorobenzole ...	$C_{12} H_3 Cl_3$	1·5563	0·0502	46	3836	346	31

In this case there is also an increase both of actual refraction and dispersion, and a decrease of sensitiveness; but when the density of the chlorinated products is taken into account, the result is a great diminution in each of the optical properties.

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* In these cases $\mu_G - \mu_A$ is taken as the measure of dispersion, since H was invisible through nitrobenzole.

† Calculated on the assumption that the specific refractive energy of a mixture is the mean of the specific refractive energies of its constituents.

The Substitution of Chlorine by Bromine.

Of this we have the following instances:—

Substance.	Formula.	Refractive index A.	Dispersion.	Sensitiveness.	Specific refractive energy.	Specific dispersion.	Specific sensitiveness.
Terchloride of Phosphorus ...	PCl_3	1·5062	394	58	3489	271	40
Terbromide of Phosphorus ...	PBr_3	1·6730	808	64	2338	280	22
Chloroform	$C_2 HCl_3$	1·4400	220	54	2949	148	37
Bromoform	$C_2 HBr_3$	1·5554	418	55	2107	158	21
Bichloride of Chlorethylene...	$C_4 H_3 Cl, Cl_2$	1·4619	228	59	3259	160	42
Bibromide of Chlorethylene...	$C_4 H_3 Cl, Br_2$	1·5430	354	56	2415	157	25
Bibromide of Bromethylene...	$C_4 H_3 Br, Br_2$	1·5809	430	50	2220	164	19

Here in each case the bromine has greatly increased the refraction; but that this is owing to its great weight is evident from the fact that the specific refractive energy is much diminished. The dispersion is increased, but this is very nearly counterbalanced by the increase of weight. The sensitiveness is diminished, at least in the ethylene group.

It will be observed that, in each of the five cases mentioned in this section where there are two substitution products, the lower one is intermediate between the original substance and the higher product.

These observations put us in a position to consider the question, Does an element retain its special influence on the rays of light with whatever other elements it may be combined?

As the specific refractive energy of a mixture, or a feeble combination such as alcohol and water, is approximately the mean of the specific refractive energies of its constituents, we are prepared to find the rule holding good in more distinct chemical compounds. In the only case in which we have been able to try it among liquid elements, namely terbromide of phosphorus, the result was pretty near; but there is no doubt that chemical combination often greatly changes the optical as it does the other properties of elementary bodies.

Yet it is quite conceivable that an element may retain a specific influence on the rays of light through many if not all its compounds; and this view certainly finds some support in our experiments. Witness the fact of the great increase both of refraction and dispersion caused by the addition of nitrogen, whether combined with oxygen or not, to compounds of carbon and hydrogen (see Appendix I., Nos. 32, 52–55, 57–62, 75, 76). But when we look more narrowly at the numbers, we find this general permanence of special optical properties subject to much modification. Thus the difference in the optical properties of some isomeric bodies shows that such a generalizatien cannot be strictly true. Again, we may examine the different cases of replacement of hydrogen by oxygen mentioned above; and as in each case the atomic volume of the substitution-product is the same, or nearly so, as the atomic volume of the primary compound, the comparison is peculiarly legitimate. We infer at once that oxygen in combination is actually more refractive and dispersive than hydrogen, but that, if we take into account its much higher density, its specific refractive energy is less. But when we come to compare the different cases quantitatively, we see that a good deal depends on the peculiar nature of the compound. In the following Table the effect of the replacement of two equivalents of hydrogen by two of oxygen is given both with respect to refraction and dispersion. The specific refractive energy of ν is taken as the best exponent of the influence of refraction, and $\mu_H - \mu_A$, divided by density, is assumed, as before, for the specific dispersion.

Substance.	Atomic volume.	Specific refractive energy (ν).	Effect of substitution.	Specific dispersion.	Effect of substitution.
Alcohol	58	444	......	190	......
Acetic Acid	57	344	−100	162	− 28
Carvene	62	530	......	305	......
Carvole	63	501	− 29	362	+ 57
Eugenic Acid	64	474	− 27	463	+101

Hence we find that the substitution of two equivalents of oxygen for two of hydrogen has produced a far greater reduction in specific refractive energy in the case of alcohol than in that of the essential oil; while in specific dispersion it has produced a reduction in the one case, and an augmentation in the other.

As the main conclusions have been marked by italics under each head as they were arrived at, they are not recapitulated; but the following may be taken as a larger generalization deduced from them, and approximately if not absolutely true. *Every liquid has a specific refractive energy composed of the specific refractive energies of its component elements, modified by the manner of combination, and which is unaffected by change of temperature, and accompanies it when mixed with other liquids.* The product of this specific refractive energy, and the density, at any given temperature, is, when added to unity, the refractive index.

APPENDIX I.

Table of refractive indices of the lines A, D, H at different temperatures.

The initials in the column headed "From whose laboratory," are those of Messrs. G. B. BUCKTON, A. H. CHURCH, WARREN DE LA RUE, E. FRANKLAND, J. H. GLADSTONE, A. W. HOFMANN, W. ODLING, C. GREVILLE WILLIAMS, and A. W. WILLIAMSON.

The sign ? attached to a liquid denotes that the purity of the specimen is doubted.

An asterisk * attached to a degree of temperature signifies that the observations at that temperature were made on a different occasion to the observations at other temperatures.

Specific gravities not determined from the specimens examined are included in brackets.

No.	Liquid.	From whose laboratory.	Specific gravity.	Temperature of observation.	Refractive indices.		
					A.	D.	H.
1.	Methylic Alcohol	E. F.	0·7972 at 20 °C.	20°	1·3264	1·3299	1·3395
				37	1·3205	1·3238	1·3330
2.	Ditto from oxalate	J. H. G.	0·796 at 20	20	1·3268	1·3297	1·3396
				29·5	1·3230	1·3262	1·3359
3.	Amylic Alcohol	J. H. G.	0·8179 at 15·5	24·5	1·3988	1·4030	1·4161
				41	1·3924	1·3966	1·4093
4.	Caprylic Alcohol......................	C. G. W.	0·8214 at 15·5	27	1·4157	1·4202	1·4351
				47	1·4073	1·4118	1·4266
5.	Iodide of Methyl......................	A. W. W.	2·1912 at 20	23·5	1·5203	1·5307	1·5670
				29·5	1·5104	1·5202	1·5549
6.	Iodide of Ethyl	A. W. W.	1·9228 at 20	23·5	1·5003	1·5095	1·5420
				36	1·4918	1·5006	1·5326
				48	1·4841	1·4934	1·5250
7.	Iodide of Propyl......................	A. W. H.	1·7117 at 20	8·5	1·5001	1·5095	1·5418
				20	1·4934	1·5024	1·5342
				30	1·4871	1·4963	1·5272
8.	Iodide of Amyl	J. H. G.	1·4950 at 20	17·5	1·4816	1·4892	1·5149
				37	1·4720	1·4797	1·5046
9.	Formic Ether	A. W. W.	0·9088 at 20	22	1·3540	1·3582	1·3694
				31	1·3500	1·3540	1·3652
				40	1·3456	1·3494	1·3608
10.	Acetic Ether	A. W. W.	0·8648 at 20	20	1·3645	1·3685	1·3798
				28	1·3606	1·3644	1·3755
11.	Acetic Ether	J. H. G.	0·8972 at 20	23·5	1·3653	1·3692	1·3809
				33	1·3606	1·3643	1·3757
				41	1·3563	1·3602	1·3711
12.	Propionic Ether	A. W. W.	0·8555 at 20	22·5	1·3696	1·3736	1·3860
				32	1·3657	1·3698	1·3819
				42	1·3610	1·3651	1·3771
13.	Butyric Ether..........................	A. W. W.	0·8778 at 20	23	1·3850	1·3888	1·4018
				40	1·3768	1·3808	1·3933
14.	Valerianic Ether......................	J. H. G.	0·868 at 20	18	1·3916	1·3958	1·4089
				32·5	1·3856	1·3898	1·4024
15.	Acetate of Amyl......................	J. H. G.	0·8680 at 20	24·5	1·3910	1·3950	1·4081
				34·5	1·3867	1·3905	1·4037
				44	1·3817	1·3859	1·3985
16.	Ditto, second specimen	J. H. G.	....	8·5	1·3944	1·3988	1·4113
				21·5	1·3886	1·3928	1·4058
				35	1·3820	1·3866	1·3990
17.	Acetate of Capryl ?..................	C. G. W.	....	27·5	1·4045	1·4092	1·4255
				40	1·3972	1·4020	1·4181

TABLE (continued).

No.	Liquid.	From whose laboratory.	Specific gravity.	Temperature of observation.	Refractive indices.		
					A.	D.	H.
			°C.	°			
18.	Hydride of Œnanthyl	J. H. G.	0·7090 at 20	9·5	1·3956	1·3996	1·4135
				22	1·3888	1·3931	1·4059
				36	1·3811	1·3854	1·3976
19.	Hydride of Capryl	J. H. G.	0·7191 at 20	9	1·4022	1·4065	1·4197
				28·5	1·3931	1·3972	1·4097
				41	1·3870	1·3911	1·4032
20.	Mercuric Methyl?	G. B. B.	(3·069)	8·5*	1·5274	1·5378	1·5726
				15*	1·5262	1·5355	1·5694
				26·5	1·5197	1·5296	1·5626
21.	Mercuric Ethyl?	G. B. B.	(2·444)	8·5*	1·5300	1·5397	1·5729
				24·5	1·5124	1·5217	1·5538
22.	Stannic Ethyl-methyl?	E. F.	1·222 at 20	19	1·4555	1·4625	1·4868
				34·5	1·4479	1·4747	1·4783
23.	Stannic Ethyl?	G. B. B.	1·192 at 20	23	1·4606	1·4673	1·4905
				35	1·4551	1·4621	1·4844
				48	1·4481	1·4549	1·4769
24.	Triethylarsine	A. W. H.	....	19·5	1·4598	1·4669	1·4919
				26·5	1·4588	1·4657	1·4906
25.	Acetic Acid	A. H. C.	1·0592 at 20	24	1·3674	1·3718	1·3846
				34·5	1·3635	1·3680	1·3803
				45	1·3596	1·3634	1·3757
26.	Acetone	J. H. G.	0·8117 at 15·5	25·5	1·3540	1·3580	1·3706
				40	1·3469	1·3512	1·3631
27.	Amylene	A. W. W.	0·7151 at 20	23	1·3832	1·3878	1·4028
				35	1·3786	1·3834	1·3982
28.	Carbonic Ether	E. F.	0·972 at 20	22	1·3773	1·3810	1·3936
				31	1·3746	1·3787	1·3898
				40	1·3692	1·3734	1·3846
29.	Boracic Ether	E. F.	0·876 at 20	22·5	1·3664	1·3698	1·3815
				40·5	1·3578	1·3604	1·3724
30.	Silicic Ether	E. F.	0·932 at 20	20	1·3781	1·3821	1·3940
				33·5	1·3724	1·3768	1·3881
31.	Salicylate of Methyl	J. H. G.	1·176 at 20	21	1·5206	1·5319	1·5810
				37	1·5140	1·5253	1·5735
32.	Nitrate of Amyl	W. D. L. R.	1·0008 at 20	10	1·4109	1·4157	1·4320
				22·5	1·4053	1·4097	1·4256
				36·5	1·3988	1·4035	1·4191
33.	Chloroform	J. H. G.	1·498 at 20	18	1·4411	1·4463	1·4630
				30	1·4346	1·4397	1·4561
				44	1·4253	1·4308	1·4471
34.	Bromoform	J. H. G.	2·636 at 12	15·5	1·5579	1·5674	1·5998
				29	1·5505	1·5598	1·5921
				39	1·5437	1·5531	1·5846
35.	Dutch Liquid	J. H. G.	....	21	1·4175	1·4221	1·4371
				38	1·4082	1·4126	1·4276
36.	Bibromide of Bromethylene	A. W. H.	2·616 at 20	18	1·5819	1·5915	1·6249
				39·5	1·5701	1·5787	1·6112
37.	Bibromide of Chlorethylene	W. D. L. R.	2·2477 at 20	13	1·5477	1·5559	1·5839
				24	1·5413	1·5495	1·5770
38.	Bichloride of Chlorethylene	W. D. L. R.	1·4177 at 20	13	1·4661	1·4714	1·4892
				29·5	1·4563	1·4619	1·4789
39.	Benzole	A. H. C.	0·8667 at 20	10·5	1·4879	1·4975	1·5305
				23	1·4806	1·4900	1·5225
				39	1·4703	1·4793	1·5108
40.	Parabenzole	A. H. C.	0·8469 at 20	20	1·4814	1·4903	1·5216
41.	Toluole	A. H. C.	0·865 at 20	25·5	1·4709	1·4794	1·5090
				32·5	1·4672	1·4755	1·5048
				39	1·4629	1·4710	1·5001

TABLE (continued).

No.	Liquid.	From whose laboratory.	Specific gravity.	Temperature of observation.	Refractive indices.		
					A.	D.	H.
42.	Paratoluole	A. H. C.	0·8333 at 20 °C.	28°	1·4667	1·4751	1·5030
				40	1·4590	1·4671	1·4944
43.	Toluole	W. O.	0·8658 at 20	14	1·4869	1·4957	1·5271
				33	……	1·4856	
44.	Xylole	W. O.	0·866 at 20	11	1·4888	1·4982	1·5300
				28	1·4788	1·4879	1·5192
				42	1·4716	1·4805	1·5116
45.	Cumole (from Cuminic Acid)	A. H. C.	0·871 at 20	7	1·4898	1·4983	1·5280
				27·5	1·4783	1·4864	1·5148
46.	Cumole (from impure Wood-spirit)	J. H. G.	0·858 at 20	8·5	1·4687	1·4759	1·5008
				24	1·4608	1·4680	1·4919
				34	1·4555	1·4634	1·4848
47.	Pseudocumole	W. D. L. R.	0·8692 at 20	12·5	1·4843	1·4932	1·5236
				35·5	1·4728	1·4812	1·5093
48.	Cymole	A. H. C.	0·861 at 20	8	1·4760	1·4834	1·5076
				29	1·4648	1·4717	1·4957
49.	Cymole (from Camphor)	W. D. L. R.	0·8565 at 20	12	1·4731	1·4803	1·5050
				26	1·4659	1·4729	1·4975
				36	1·4614	1·4684	1·4927
50.	Chlorobenzole	W. D. L. R.	1·108 at 20	9	1·5194	1·5290	1·5636
				27·5	1·5095	1·5189	1·5528
51.	Trichlorobenzole	A. W. H.	1·450 at 20	20	1·5563	1·5671	1·6065
				37	1·5495	1·5600	1·5983
52.	Nitrobenzole	A. H. C.	1·159 at 20	25	1·5331	1·5465	1·5832 G.
				38	1·5266	1·5399	1·5766 G.
53.	Dinitrobenzole in 2 equivs. of nitrobenzole	A. H. C.	1·267 at 20	23·5	1·5460	1·5600	1·5994 G.
				35	1·5404	1·5542	1·5932 G.
				56	1·5296	1·5425	1·5816 G.
54.	Aniline	A. H. C.	1·027 at 16	21·5	1·5644	1·5784	1·6297
				37	1·5567	1·5701	
				42	1·5537	1·5676	1·6183
				47	1·5520	1·5647	1·6145
55.	Amyl-aniline	A. W. H.	0·9177 at 20	23·5	1·5114	1·5222	1·5622
				42	1·5035	1·5138	1·5532
56.	Hydrate of Cresyl	W. D. L. R.	1·0364 at 20	11·5	1·5341	1·5454	1·5824
				32	1·5281	1·5377	1·5733
57.	Pyridine	A. W. H.	0·9738 at 20	21·5	1·4940	1·5030	1·5387
				36	1·4860	1·4951	1·5301
58.	Picoline	A. H. C.	(0·955)	22·5	1·4888	1·4980	1·5314
				37·5	1·4803	1·4890	1·5213
				52	1·4718	1·4807	1·5122
59.	Lutidine	A. H. C.	(0·936)	8·5*	1·4932	1·5028	1·5353
				22·5	1·4894	1·4987	1·5308
60.	Collidine	A. H. C.	(0·921)	23·5	1·4927	1·5013	1·5329
				45	1·4820	1·4907	1·5210
61.	Chinoline	C. G. W.	(1·081 at 10)	24	1·5567	1·5687	1·6198
				35	1·5466	1·5587	1·6084
				37	1·5496	1·5617	1·6124
62.	Lepidine	C. G. W.	1·072 at 15	21	1·6039	1·6189	1·6822
				47	1·5909	1·6054	1·6473 G.
63.	Hydrocarbon from Anise	A. H. C.	0·858 at 20	11	1·4653	1·4718	1·4921
				30	……	1·4625	
64.	„ Turpentine	J. H. G.	0·8644 at 20	10*	1·4669	1·4734	1·4934
				24	1·4596	1·4653	1·4845
				47	1·4487	1·4545	1·4730
65.	„ Carraway	J. H. G.	0·8529 at 20	14	1·4640	1·4701	1·4901
				37	1·4529	1·4589	1·4783

TABLE (continued).

No.	Liquid.	From whose laboratory.	Specific gravity.	Temperature of observation.	Refractive indices.		
					A.	D.	H.
66.	Hydrocarbon from Thyme.........	J. H. G.	0·8635 at 20 °C.	25°	1·4594	1·4652	1·4856
				35·5	1·4545	1·4606	1·4805
67.	„ Bay	J. H. G.	0·851 at 20	23	1·4545	1·4610	1·4818
				43	1·4468	1·4528	
68.	„ Bergamot ...	J. H. G.	0·8467 at 20	26·5	1·4574	1·4640	1·4865
				38	1·4517	1·4578	1·4800
69.	„ Cloves	J. H. G.	0·9041 at 20	17	1·4918	1·4985	1·5209
				28·5	1·4870	1·4936	1·5157
				39	1·4828	1·4892	1·5110
70.	„ Cubebs	J. H. G.	0·927 at 20	10·5	1·4988	1·5055	1·5294
				20	1·4950	1·5014	1·5252
				31	1·4905	1·4977	1·5209
71.	Carvole	J. H. G.	0·9530 at 20	12·5	1·4913	1·4992	1·5270
				24·5	1·4862	1·4935	1·5196
				34	1·4812	1·4884	1·5145
72.	Eugenic Acid	J. H. G.	1·064 at 20	18	1·5285	1·5394	1·5780
				27·5	1·5244	1·5347	1·5722
73.	Camphor of Peppermint...........	....	0·8786 at 43	30	1·4503	1·4553	1·4703
				43	1·4451	1·4505	1·4653
74.	Glycerine..............................	J. H. G.	1·261 at 17	20	1·4659	1·4705	1·4850
				30	1·4634	1·4680	1·4823
				48	1·4586	1·4631	1·4773
75.	Nitroglycerine?	J. H. G.	(1·60)	13·5	1·4683	1·4749	1·4947
				32·5	1·4596	1·4662	
76.	Nicotine	J. H. G.	1·026 at 18	18	1·5149	1·5234	1·5542
				32	1·5107	1·5194	1·5493
77.	Terbromide of Phosphorus	J. H. G.	2·88 at 20	25	1·6698	1·6866	1·7506
				36	1·6627	1·6792	1·7422
78.	Terchloride of Phosphorus	J. H. G.	1·453 at 20	25·5	1·5030	1·5118	1·5418
				38	1·4957	1·5042	1·5334
79.	Oxychloride of Phosphorus	J. H. G.	1·680 at 20	17	1·4810	1·4882	1·5118
				26	1·4756	1·4832	1·5067

The determinations of iodide of propyl were added, and those of acetic acid and terchloride of phosphorus were altered during the printing of the paper.

APPENDIX II.—Table of Refractive Indices.

The liquids in this Table are arranged according to their power of refracting the line A at 20° C.

Liquid.	Temp.	Refractive indices.							
		A.	B.	C.	D.	E.	F.	G.	H.
	°C.								
Phosphorus................................	35	2·0389	......	......	2·0746	......	2·1201	2·1710	2·2267?
Phosphorus in Bisulphide of Carbon..	?	1·9209	1·9314	......	1·9527	1·9744	1·9941	2·0361	2·0746
Terbromide of Phosphorus	25	1·6698	1·6752	......	1·6866	......	1·7083	1·7300	1·7506
Bisulphide of Carbon.....................	11	1·6142	1·6207	1·6240	1·6333	1·6465	1·6584	1·6836	1·7090
Lepidine....................................	21	1·6039	1·6094	......	1·6189	......	1·6403	1·6615	1·6822
Bibromide of Bromethylene	18	1·5819	1·5851	......	1·5915	......	1·6037	1·6149	1·6249
Rectified Oil of Cassia	28	1·5649	1·5699	1·5727	1·5801	1·5909	1·6014	1·6244	......
Aniline	21·5	1·5644	1·5684	......	1·5774	......	1·5951	1·6125	1·6297
Chinoline	24	1·5567	1·5617	......	1·5687	......	1·5879	1·6030	1·6198
Trichlorobenzole	20	1·5563	1·5602	......	1·5671	......	1·5809	1·5945	1·6065
Bromoform.................................	15·5	1·5579	1·5610	1·5628	1·5674	1·5737	1·5790	1·5901	1·5998
Dinitrobenzole in nitrobenzole.........	23·5	1·5460	1·5506	......	1·5600	......	1·5791	1·5994	......
Bibromide of Chlorethylene	12·5	1·5472	1·5500	......	1·5554	......	1·5659	1·5748	1·5830

TABLE (continued).

Liquid.	Temp.	Refractive indices.							
		A.	B.	C.	D.	E.	F.	G.	H.
	°C.								
Nitrobenzole	25	1·5331	1·5374	1·5398	1·5465	1·5554	1·5643	1·5832	......
Hydrate of Phenyl	13	1·5377	1·5416	1·5433	1·5488	1·5564	1·5639	1·5763	1·5886
Hydrate of Cresyl	11·5	1·5341	1·5377	......	1·5445	......	1·5573	1·5699	1·5813
Eugenic Acid	18	1·5285	1·5321	1·5341	1·5394	1·5464	1·5528	......	1·5780
Mercuric Methyl	26·5	1·5197	1·5232	......	1·5296	......	1·5368	1·5526	1·5626
Salicylate of Methyl	21	1·5206	1·5241	1·5263	1·5319	1·5402	1·5478	1·5640	1·5810
Iodide of Methyl	16	1·5203	1·5234	......	1·5307	1·5377	1·5440	1·5558	1·5670
Mercuric Ethyl	8·5	1·5300	1·5333	......	1·5397	......	1·5518	1·5634	1·5729
Nicotine	18	1·5149	1·5174	......	1·5234	......	1·5346	1·5449	1·5542
Chlorobenzole	9	1·5194	1·5223	......	1·5290	......	1·5418	1·5530	1·5636
Amyl-aniline	23·5	1·5114	1·5150	1·5168	1·5222	1·5292	1·5361	1·5491	1·5622
Terchloride of Phosphorus	23·5	1·5052	1·5088	......	1·5148	......	1·5252	1·5357	1·5446
Iodide of Ethyl	23·5	1·5003	1·5034	......	1·5095	1·5156	1·5214	1·5321	1·5420
Rectified Oil of Santal-wood	25·5	1·4954	1·4977	......	1·5015	......	1·5093	1·5161	1·5223
Hydrocarbon from Cubebs	10·5	1·4988	1·5012	......	1·5055	......	1·5145	1·5227	1·5294
Pyridine	21·5	1·4940	1·4967	......	1·5030	......	1·5155	1·5278	1·5387
Lutidine	22·5	1·4894	1·4924	......	1·4987	......	1·5100	1·5204	1·5308
Collidine	23·5	1·4927	1·4958	......	1·5013	......	1·5127	1·5232	1·5329
Hydrocarbon from Cloves	17	1·4918	1·4944	......	1·4985	......	1·5064	1·5140	1·5209
Pseudocumole	12·5	1·4843	1·4872	......	1·4932	......	1·5040	1·5146	1·5236
Iodide of Amyl	17·5	1·4816	1·4843	......	1·4892	1·4941	1·4987	1·5074	1·5149
Oxychloride of Phosphorus	17	1·4810	1·4840	......	1·4882	......	1·4967	1·5047	1·5118
Benzole	10·5	1·4879	1·4913	1·4931	1·4975	1·5036	1·5089	1·5202	1·5305
Toluole	14	1·4869	1·4898	......	1·4957	......	1·5072	1·5174	1·5271
Cymole	29	1·4648	1·4671	......	1·4717	1·4766	1·4808	1·4866	1·4957
Nitroglycerine	13·5	1·4683	1·4706	......	1·4749	......	1·4824	1·4899	1·4947
Hydrocarbon from Portugal	25	1·4617	1·4640	......	1·4684	......	1·4758	1·4826	1·4894
Cumole (2nd specimen)	8·5	1·4687	1·4709	......	1·4759	......	1·4853	1·4936	1·5008
Stannic Ethyl	23	1·4606	1·4629	......	1·4673	......	1·4758	1·4838	1·4905
Bichloride of Chlorethylene	13	1·4661	1·4680	......	1·4714	......	1·4784	1·4841	1·4892
Hydrocarbon from Turpentine	24	1·4596	1·4616	......	1·4653	1·4691	1·4724	1·4790	1·4845
Hydrocarbon from Carraway	24	1·4594	1·4615	......	1·4652	......	1·4724	1·4789	1·4844
Hydrocarbon from Bergamot	26·5	1·4574	1·4598	......	1·4640	......	1·4721	1·4798	1·4865
Rectified Oil of Citronella	19	1·4598	1·4619	......	1·4655	......	1·4730	1·4795	1·4860
Hydrocarbon from Bay	23	1·4545	1·4567	......	1·4610	......	1·4690	1·4756	1·4818
Stannic Ethyl-methyl	19	1·4555	1·4578	1·4590	1·4625	1·4674	1·4716	1·4795	1·4868
Chloroform	10	1·4438	1·4457	1·4466	1·4490	1·4526	1·4555	1·4614	1·4661
Caprylic Alcohol	9·5	1·4230	1·4246	1·4255	1·4279	1·4309	1·4338	1·4386	1·4429
Nitrate of Amyl	10	1·4109	1·4127	......	1·4157	......	1·4219	1·4274	1·4320
Amylic Alcohol	25	1·3981	1·3999	......	1·4024	......	1·4078	1·4122	1·4161
Hydride of Capryl	9	1·4022	1·4037	......	1·4065	......	1·4076	1·4141	1·4197
Hydride of Œnanthyl	9·5	1·3956	1·3968	......	1·3996	......	1·4045	1·4087	1·4135
Acetate of Amyl	8·5	1·3944	1·3958	......	1·3998	......	1·4035	1·4077	1·4113
Butyric Ether	23	1·3850	1·3864	......	1·3888	......	1·3938	1·3981	1·4018
Amylene	8	1·3850	1·3866	......	1·3896	......	1·3944	1·3992	1·4033
Carbonic Ether	22	1·3773	1·3785	......	1·3810	......	1·3856	1·3896	1·3936
Propionic Ether	22·5	1·3696	1·3713	......	1·3736	......	1·3785	1·3827	1·3860
Boracic Ether	22·5	1·3664	......	......	1·3698	......	1·3742	1·3785	1·3815
Acetic Ether	20	1·3645	1·3658	......	1·3685	......	1·3728	1·3766	1·3798
Alcohol	15	1·3600	1·3612	1·3621	1·3638	1·3661	1·3683	1·3720	1·3751
Acetone	25·5	1·3540	1·3554	......	1·3582	......	1·3629	1·3670	1·3706
Formic Ether	22	1·3540	1·3553	......	1·3582	......	1·3627	1·3666	1·3694
Ether	15	1·3529	1·3545	1·3554	1·3566	1·3590	1·3606	1·3646	1·3683
Water	15	1·3284	1·3300	1·3307	1·3324	1·3347	1·3366	1·3402	1·3431
Methylic Alcohol	20	1·3264	1·3277	......	1·3299	......	1·3330	1·3369	1·3395

P.S. [*Received May* 28.]—It was not till after this paper was read that we became aware of the existence of an elaborate treatise by Dr. Schrauf, "On the Dependence of the Velocity of Light on the Density of Bodies," in Poggendorff's Annalen, cxvi. 193, in which he investigates the question mathematically, taking as the basis of his calculations our former experiments, and those of Deville, Weiss, and others. Our own line of thought has many points of analogy with that pursued by him, but there is this difference in the conclusion: he believes that $\frac{A^2-1}{D}$ and $\frac{B}{D^2}$ $\left(\text{or in our notation } \frac{\nu^2-1}{D} \text{ and } \frac{\varkappa}{D^2}, \text{ D being the density}\right)$ are the constants at all temperatures, and are the functions on which depend the optical properties of mixtures; while we are led by our new experiments to accord that quality rather to $\frac{\nu-1}{D}$, and to doubt any such simple formula as $\frac{\varkappa}{D^2}$ for the changes of dispersion. To this point we propose to recur at some future period if we have the opportunity.

There is one point in reference to our method of observation which seems to call for a remark. Schrauf thinks that there is a slight change in the refringent angle of our prism on its being heated. Now our hollow prism has glass ends as well as glass sides; but supposing such a change actually occurs, it is evident it will produce a uniform error running through all our observations in Section I. This may be the reason why at high temperatures the observed is almost always less than the calculated index; but as bisulphide of carbon and water agree so closely with either his or our theory, this source of error must be extremely minute.

We await with curiosity the publication of the experiments referred to in Dr. Schrauf's short note, "On the Velocity of Light and Chemical Composition," in the April Number of Poggendorff's Annalen.